Total Maximum Daily Load For Pathogen Indicators Maquoketa River, Iowa

2006

Iowa Department of Natural Resources
Watershed Improvement Section

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1. Introduction and Executive Summary

Table 1. Summary of the Maquoketa River TMDL.

Waterbody Name:	Maquoketa River (segment IA 01-MAQ-0060_1)
County:	Jones and Jackson
Use Designation Class:	A1 (Primary contact recreation) B(WW1) (Aquatic life)
Major River Basin:	Mississippi
Pollutants:	Pathogens (Fecal coliform)
Pollutant Sources:	Nonpoint
Impaired Use(s):	A1 (Primary contact recreation)
Watershed Area:	613,500 acres (959 square miles)
Stream Length:	26.9 miles
Targeted Fecal Coliform Load:	Daily maximum: 235 CFU/100 ml Geometric mean: 126 CFU/100 ml
Existing Total Fecal Coliform Load:	Up to 20,000 CFU/100 ml (single sample)
Wasteload Reduction to Achieve Target:	37-80% reduction in permitted effluent limits
Load Reduction to Achieve Target:	78% in surface runoff loads 40% in other NPS bacterial loads (e.g. septics and cattle in streams)
Margin of Safety	Explicitly set by limiting fecal coliform concentrations at the values set for *E. coli* standards

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. One segment on the Maquoketa River was included in the 1998 and subsequent 2004 Iowa 303(d) List as impaired by excessive indicator bacteria (fecal coliform) (segment IA 01-MAQ-0060_1). The purpose of this TMDL is to calculate the maximum allowable pathogen load for the impaired segment of the Maquoketa River that will meet water quality standards.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available. A monitoring plan will be used to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

Section 5.0 of this TMDL includes a description of planned monitoring. The TMDL will have two phases. Phase 1 will consist of setting specific and quantifiable targets for fecal coliform. Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

Monitoring is essential to all TMDLs in order to:

- Assess the future beneficial use status;
- Determine if the water quality is improving, degrading or remaining status quo;
- Evaluate the effectiveness of implemented best management practices.

The additional data collected will be used to determine if the implemented TMDL and watershed management plan have been or are effective in addressing the identified water quality impairment. The data and information can also be used to determine if the TMDL has accurately identified the required components (i.e. loading/assimilative capacity, load allocations, in-stream response to pollutant loads, etc.) and if revisions are appropriate.

This TMDL has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7. These regulations and consequent TMDL development are summarized below:

1. Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:

The Maquoketa River, subsegment number one (IA 01-MAQ-0060_1), located between the confluences of the Maquoketa and North Fork Maquoketa Rivers and the Maquoketa River and Farm Creek in S10, T85N, R01W, Jones County.

2. Identification of the pollutant and applicable water quality standards:

The pollutants causing the water quality impairments are pathogen indicators (fecal coliform). Designated uses assigned to the above-identified segments include: primary contact recreation and aquatic life. The Class A (primary contact recreation) uses remain assessed (monitored) as "not supported" due to consistently high levels of indicator bacteria. The Class B(WW1) aquatic life uses were assessed as "fully supported/threatened." The applicable water quality standards for bacteria (*E. coli*) are a seasonal geometric mean of 126 CFU/100 ml of water and a single maximum value of 235 CFU/100 ml.

3. Quantification of the pollutant load that may be present in the waterbody and still allows attainment and maintenance of the water quality standards:

Because bacteria are expressed as a density of bacterial colonies, mass load is not relevant for assessing the level of contamination. The targets are therefore expressed as a concentration, with the units being number of organisms (colony forming units, or CFU) per 100 ml of water as is the standard. The target of this

TMDL is an *E. coli* level which does not exceed a geometric mean of 126 CFU/100 ml of water or a sample maximum of 235 CFU/100 ml of water. This criteria applies during the recreational season from March 15 to November 15 of each year.

4. Identification of pollution source categories:

Nonpoint sources of pathogen indicators have been identified as the main cause of the primary contact recreation use impairment for this segment of the Maquoketa River. Point sources, such as wastewater treatment plants, are also likely contributors to the total pathogen load but play a more minor role.

5. Wasteload allocations for pollutants from point sources:

The wasteload allocations for point source dischargers to Maquoketa River will be equivalent to the water quality criteria associated with the primary contact recreation beneficial use. Therefore, the WLA is a monthly geometric mean of 126 CFU/100 ml and a maximum daily value of 235 CFU/100 ml for facilities discharging directly to the impaired reach or a higher value for those contributing to tributaries of the impaired reach (Table 10).

6. Load allocations for pollutants from nonpoint sources:

The load allocations assigned to nonpoint sources of pollution for this TMDL will also be based upon the applicable water quality standards for the stream's designated use. Therefore, the load allocation is a monthly geometric mean of 126 CFU/100 ml and a maximum daily value of 235 CFU/100 ml.

7. A margin of safety:

This TMDL contains an explicit margin of safety. Specifically, the targets and allocations were set for fecal coliform bacteria at a level corresponding to the *E. coli* water quality standards.

8. Consideration of seasonal variation:

This TMDL was developed based on the Iowa water quality standards primary contact recreation season that runs from March 15 to November 15. For the technical modeling, a load duration analysis was used to assign bacterial concentrations to variable stream flow conditions so that seasonal variations could be accounted for.

9. Allowance for reasonably foreseeable increases in pollutant loads:

There was no allowance for future growth included in this TMDL because current watershed land uses are predominantly agricultural and the addition/deletion of animal feeding operations (which could increase or decrease pathogen indicator loading) cannot be predicted or quantified at this time.

10. Implementation plan:

An implementation plan is outlined in section 4 of this TMDL. The reduction of bacterial pathogen concentrations will be carried out through a combination of non-regulatory activities and monitoring for results. Nonpoint source pollution will be addressed using available programs, technical advice, information and education, and financial incentives.

2. Maquoketa River, Description and History

2.1 The Stream and its Hydrology

Table 2. Maquoketa River and its basin.

Waterbody Name:	Maquoketa River
Hydrologic Unit Code:	07060006
IDNR Waterbody ID:	IA 01-MAQ-0060_1
Location:	From confluence with Farm Creek (S10, T85N, R01W) to confluence with the North Fork Maquoketa River (S13, T85N, R02W)
Major Tributaries (Iowa):	Bear Creek, Mineral Creek, Farm Creek, and many other named tributaries
Receiving Waterbody:	Mississippi River
Total Stream Segment Length (Iowa):	26.9 miles
Watershed Area:	959 square miles

The Maquoketa River basin is located in east-central and northeast Iowa and runs northwest to southeast. The Maquoketa River originates in Fayette County and flows about 150 miles through the cities of Manchester, Monticello, and Maquoketa to its confluence with the Mississippi River near the City of Green Island. The total drainage area of the Maquoketa River is 1,879 square miles. However, the impaired segment addressed by this TMDL (as described in Table 2) excludes the North Fork Maquoketa River and segments of the river downstream from the city of Maquoketa, IA, and thus drains a sub-total of 959 square miles.

Major tributaries which flow directly into the impaired segment include Bear Creek (draining 111 square miles), Mineral Creek (draining 49 square miles), and Farm Creek (draining 24 square miles). The remaining 775 square miles of watershed above the impaired segment are drained by thirteen named tributaries totaling 129 miles in length. Table 3 summarizes pertinent information for the Maquoketa River USGS gage.

2.2 The Watershed

The total area of the Maquoketa River basin above the impaired segment is 959 square miles, sixty-five percent of which lies in the landform region called the Iowan Surface. The rest is located in the Southern Iowa Drift Plain landform. Characteristics of both landforms are described in detail below.

Table 3. USGS gaging station on the Maquoketa River.

Site number	05418500
Station Name	Maquoketa River at Maquoketa, IA
Latitude	42°05'00"
Longitude	90°37'58"
Altitude (NGVD29)	625.96
HUC	07060006
Drain area (mi.^{2})	1553
Discharge begin date	09/01/1913
Discharge end date	9/30/2005

Geology and Soils

The Iowan Surface is a geologically complex region located between the bedrock-dominated landforms of the Paleozoic Plateau region and the relatively recent glacial drift landforms of the Des Moines Lobe. The southern and southeastern border of this ecoregion is irregular and crossed by major northwest- to southeast-trending stream valleys. In the northern portion of the region, the glacial deposits are thin, and shallow limestone bedrock creates karst features such as sinkholes and sags. There are no natural lakes of glacial origin in this region, but overflow areas and backwater ponds occur on some of the larger river channels contributing to some diversity of aquatic habitat and a large number of fish species. Major soil associations include Tama-Muscatine, Dinsdale-Klinger, and Kenyon-Floyd-Clyde.

The Southern Iowa Drift Plain region covers approximately 46 percent of Iowa and contains all or part of 66 counties. This landform region was created by a combination of several older glacial ice sheets, wind-deposited loess, and the erosive power of water. These three geologic agents left the surface of the landscape more steeply rolling than the alluvial plains or glacial plains in other landform regions. The rolling Southern Iowa Drift Plain often represents the "typical" Iowa landscape, memorable to interstate travelers, artists, and photographers. The loess mantle ranges in thickness from 5 to 30 feet and is thickest near the Missouri and Mississippi rivers. In this older landscape, streams have had time to establish well-connected drainage systems that cut deeply into the land surface. Many finely-etched rills give way to ravines, then to creeks that flow part of the year, and eventually to perennial streams and rivers in major valleys. Glacial deposits in this region typically have a high clay content, which aids in building farm ponds and artificial lakes. Common wetland and riparian communities in the landform region include wooded ravines, floodplain and stream-side woodlands, and artificial lakes and ponds.

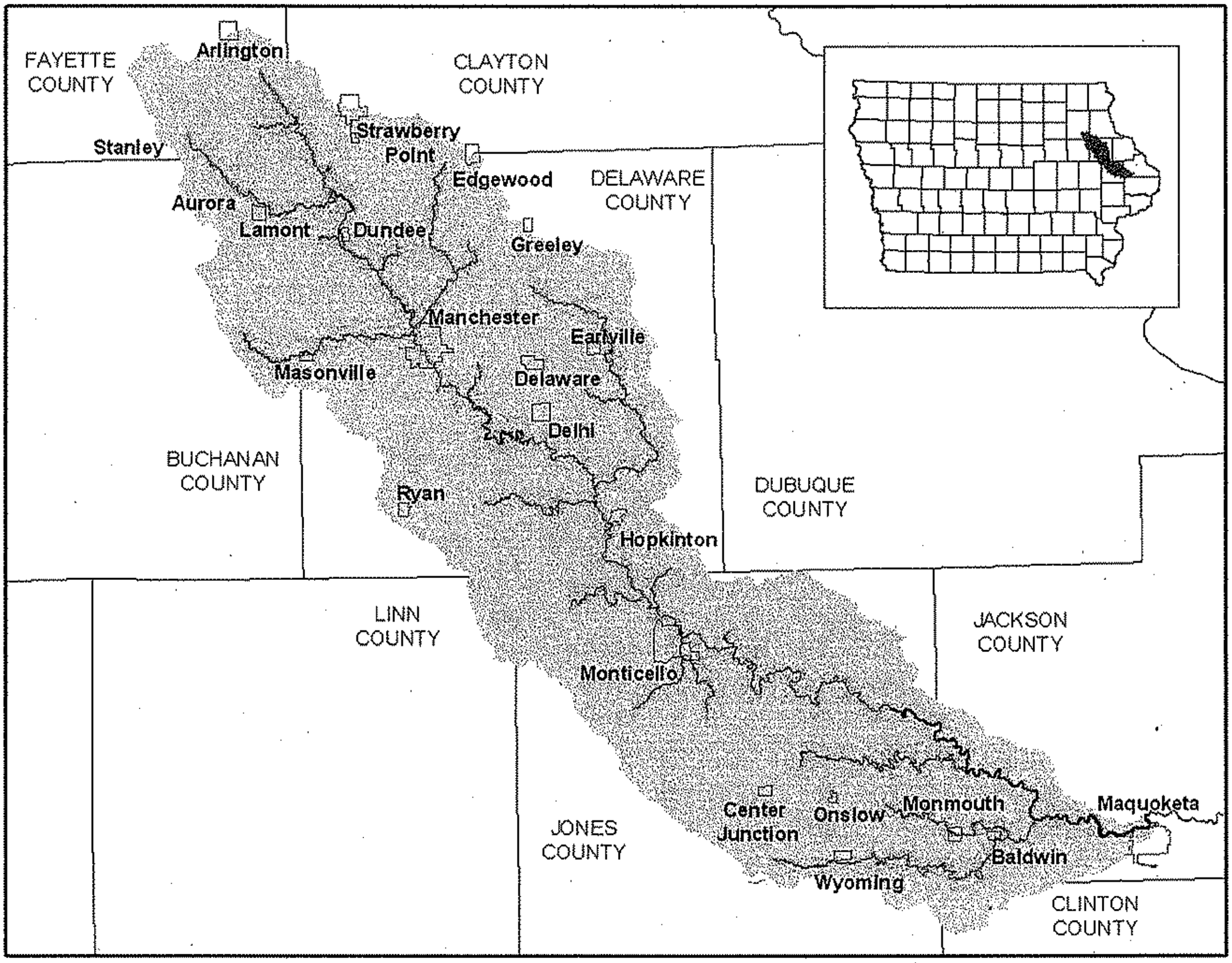

Figure 1. Map of the Maquoketa watershed above the impaired stream segment.

Land Use

Overall, agriculture is the primary land use in the project area and includes row crop farming, small grains and hay production, and pasture land (Figure 2 and Table 4). Livestock feeding operations are found throughout the watershed with beef and hog operations being the most common. These land uses are not spatially uniform across the entire watershed, however, as the upper portion tends to favor row cropping (corn and soybeans) and hog production while the lower portion of the watershed is more suitable for hay and pasture operations with beef and dairy livestock (IDNR, 2004a).

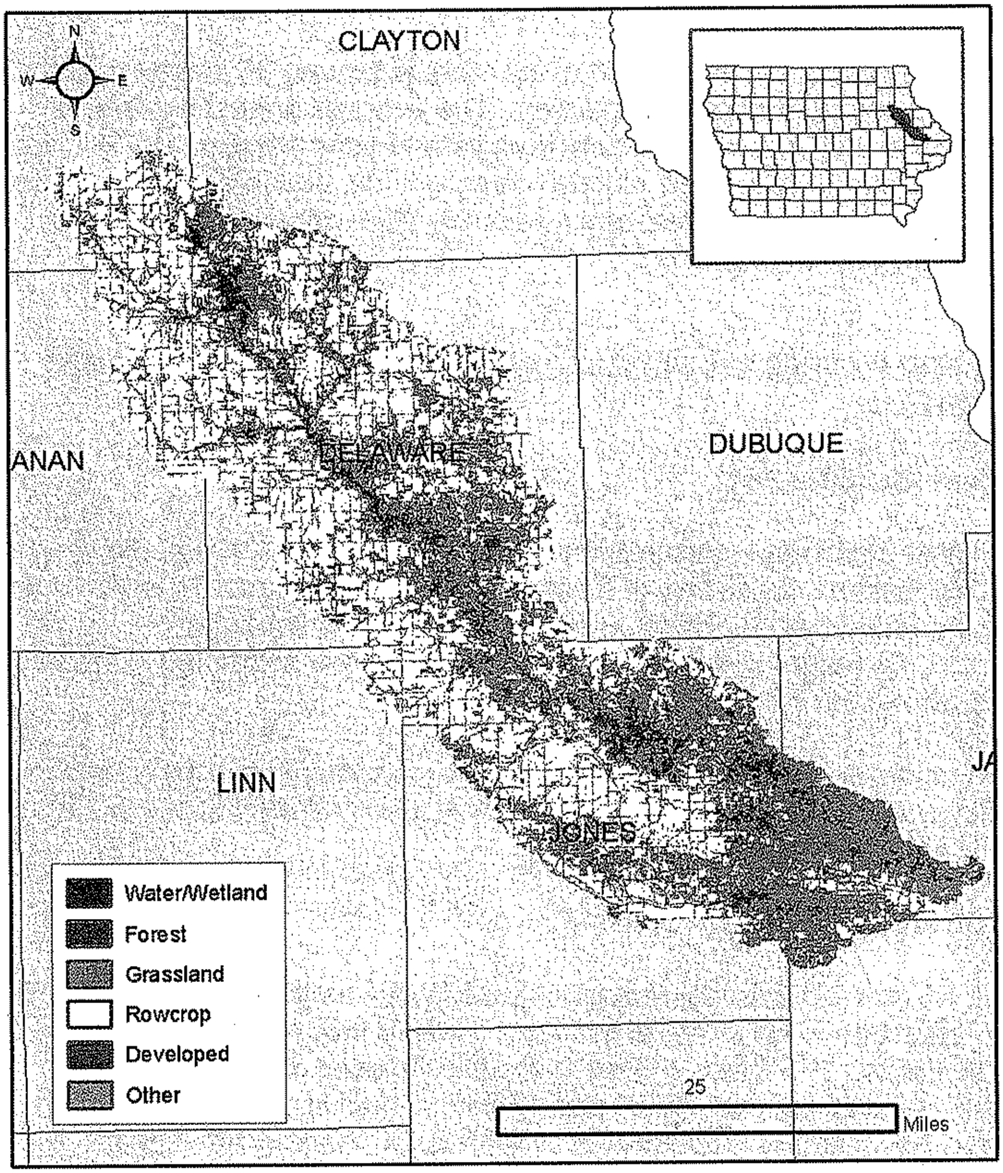

Figure 2. Land cover map in the impaired segment's watershed.

Table 4. Land use distribution in the Maquoketa River Watershed (IDNR, 2004a).

Land Use	Acres	Percent of Total
Developed	18,405	3
Cropland	36,1965	59
Pastureland	171,780	28
Forest	61,350	10
TOTAL:	613,500	100

The total annual precipitation in this part of the state is around 35 inches on average, 70% of which falls during the growing season. The average annual snowfall is approximately 33 inches but varies widely from year to year (Minger, 1991). Wildlife species present in the area include whitetail deer, red fox, beavers, raccoons, ring-necked pheasants, mourning doves, and numerous other species of songbirds, waterfowl, reptiles, and amphibians.

3. TMDL FOR PATHOGEN INDICATORS ON THE MAQUOKETA RIVER SEGMENT

3.1 Problem Identification

The 1998 Section 305(b) Assessment Report for Iowa lists the Maquoketa River as divided into five reaches consisting of 9 segments (plus Backbone Lake) for water quality assessment purposes. Backbone Lake is assessed separately but is an impoundment of the Maquoketa River. Only one of the nine segments is impaired for pathogen indicators and is covered by this TMDL.

The following paragraph is the basis for the 305b assessment and comments for the impaired Maquoketa River segment: *North Fork Maquoketa confluence to Farm Creek, Waterbody ID No.: IA 01-MAQ-0060_1.*

From the 1998 and 2004 305(b) reports:

> "Class A1 (primary contact recreation) uses were assessed (monitored) as 'not supported' based on levels of indicator bacteria that violate state water quality standards. The Class B (WW1) aquatic life uses were assessed (monitored) as 'fully supported/threatened' with a declining trend. The source of data for this assessment is the results of IDNR/UHL monthly monitoring conducted from October, 1999, to September, 2001, at the IDNR ambient station at Hwy 61 bridge NW of Maquoketa, and at five locations between Maquoketa and Canton from March to November 2001, in support of TMDL development for this stream segment."

This segment of Maquoketa River is on the State of Iowa 303(d) list of impaired waters for indicator bacteria. Bacteria sources could include wastewater treatment plant discharges, urban storm sewers, septic tanks, wildlife, runoff from fields where manure has been applied, and feedlots. Bacteria problems often follow heavy rainfall events.

Impaired Beneficial Uses and Applicable Water Quality Standards - Pathogen Indicator Water Quality Standards

The Surface Water Classification document (IDNR, 2004b) lists the designated uses for the impaired segment as Class A1 and Class B(WW1). Because the Class B(WW1) use was assessed as “fully supported,” it does not require a TMDL report to be written. However, the primary contact recreation (Class A1) beneficial use remains impaired. The Iowa Water Quality Standards (IAC, 2004) describes this use classification as follows:

- Primary contact recreational use (Class ”A1”). Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, waterskiing, and water contact recreational canoeing.

The applicable water quality standards for the primary contact recreation use are listed below in Table 5.

Table 5. *E. Coli* Bacteria Criteria (organisms/100 ml of water) for Class A waters (IAC, 2004).

Use	Geometric Mean	Sample Maximum
Class A1		
3/15 – 11/15	126	235
11/16 – 3/14	Does not apply	Does not apply
Class A2 (Only)		
3/15 – 11/15	630	2880
11/16 – 3/14	Does not apply	Does not apply
Class A2 and B(CW) or HQ		
Year-Round	630	2880
Class A3		
3/15 - 11/15	126	235
11/16 - 3/14	Does not apply	Does not apply

Relationship of E. coli to fecal coliform

In 2003, the fecal coliform standard in the Iowa Water Quality Standards was replaced by a water quality standard for *E. coli*. To explore the relationship of *E.coli* to fecal bacteria, a regression analysis was performed on the data from the Maquoketa River near Maquoketa, IA for the years between 1998-2004. The following relationship was found which demonstrates that using fecal coliform information to assess current conditions and develop percentage reduction targets may be appropriate. The TMDL targets for fecal coliform are set at the same values as the *E. coli* standard based on this analyses. The *E. coli* is expected to be a subset of the fecal coliform and the ratio should not exceed 1, which is also the upper quartile as shown in the following statistics in Table 6.

Table 6. Relationship of *E. coli* to fecal coliform.

Descriptive Statistics: Ratio of *E.coli* to fecal coliform bacteria

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Ratio	119	0	0.8782	0.0425	0.4631	0.0608	0.723	0.8500	1.0000

Data Sources

Water quality data for this TMDL assessment were obtained from the following sources:

- IDNR ambient water quality monitoring station from October 1999 to November 2004 at the Highway 61 bridge northwest of Maquoketa (Figure 3)
- IDNR/UHL targeted TMDL monitoring during 2001

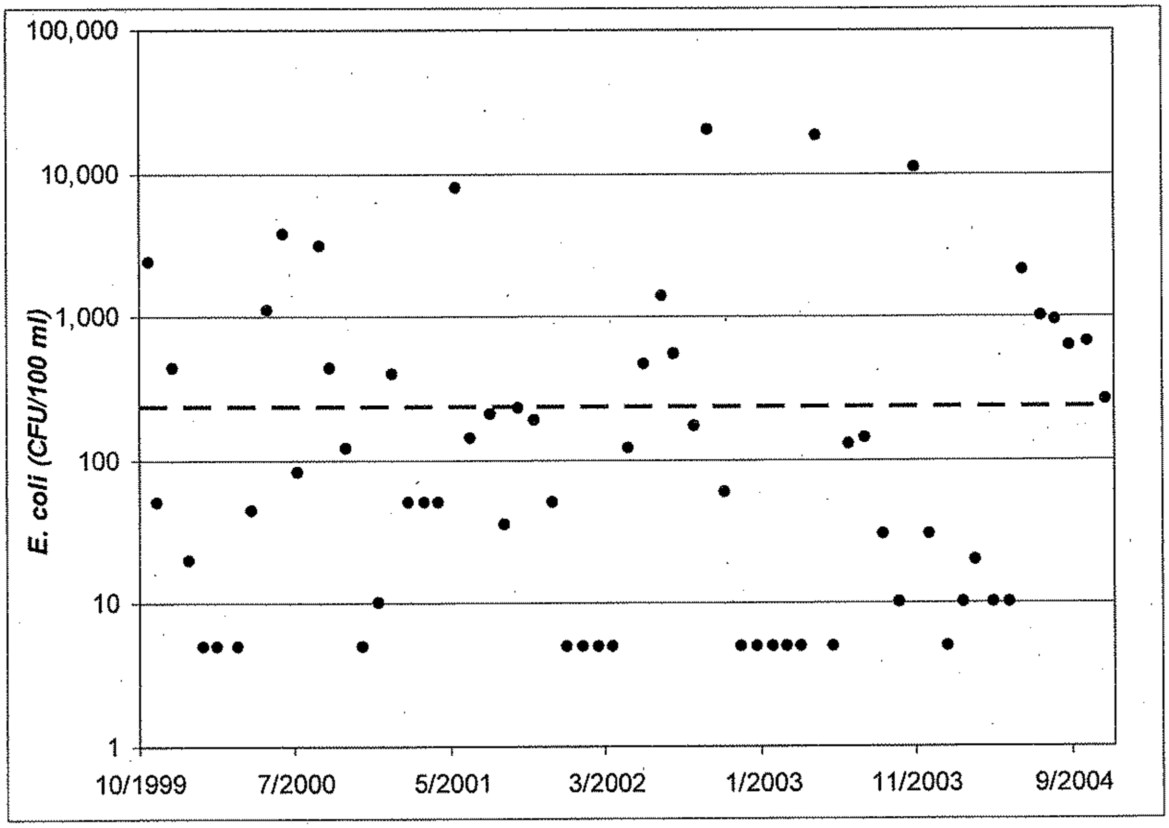

Figure 3. *E. coli* measurements in the impaired segment of the Maquoketa River (dashed line designates the single-sample maximum of 235 CFU/100 ml).

3.2 Pollution Source Assessment

The sources of bacterial pollutants can be divided into two major categories: point source and nonpoint source. These two categories are sub-divided and explained in detail in the following sections.

Point Sources

Wastewater Treatment Plants

These point sources include municipal wastewater treatment, industrial, and commercial facilities. There are four permitted facilities located in the watershed that have a fecal coliform discharge limit. Table 7a lists the permitted flow and fecal coliform concentration as compiled from the Permit Compliance System (PCS) database. Table 7b lists permitted facilities in the watershed that have no specified limitation on effluent fecal coliform, but may be potential sources. Eleven facilities are controlled discharge lagoons, which are supposed to discharge only when receiving stream flows are high. These are denoted with an asterisk in the "Facility" column.

Table 7a. Permitted wastewater treatment facilities which have fecal coliform limits in the impaired segment's watershed.

Facility Name	EPA NPDES ID	Receiving Stream	Facility	Population Equivalent	Design ADW Flow (MGD)	Design AWW Flow (MGD)	Fecal Coliform (CFU/100ml)
CAMP COURAGEOUS OF IOWA	IA0071820	UNNAMED TRIBUTARY TO MAQUOKETA RIVER	ACTIVATED SLUDGE	102	0.006	0.005	AVG. 1010; MAX. 1890
CITY OF MANCHESTER STP	IA0021032	MAQUOKETA RIVER	SEQ. BATCH REACTOR	6934	0.623	0.823	AVG. 200; MAX. 373
CITY OF MAQUOKETA STP	IA0024481	MAQUOKETA RIVER	TRICKLING FILTER	14970	1.03	1.3	MAX. 200
CITY OF MONTICELLO STP	IA0026034	MAQUOKETA RIVER	TRICKLING FILTER	6467	0.54	1.14	AVG. 200; MAX. 370

Table 7b. Other permitted facilities in Maquoketa River Watershed.

Name	EPA NPDES ID	Receiving Stream	Facility	Population Equivalent	Design ADW Flow (MGD)	Design AWW Flow (MGD)
BALDWIN CITY OF STP	IA0063398	BEAR CREEK	WASTE STABIL LAGOON*	605	0	0.053
DELAWARE CITY OF STP	IA0062855	PENN CREEK	WASTE STABIL LAGOON*	207	0.0204	0.0204
DELHI CITY OF STP	IA0047848	UNNAMED CREEK TO MAQUOKETA RIVER	WASTE STABIL LAGOON*	738	0.0629	0.0629

(Table 7b continued)

DNR BACKBONE STATE PARK (LOWER AREA)	IA0066044	DRY RUN TO MAQUOKETA RIVER	WASTE STABIL LAGOON	214	0.0093	0.0094
DNR BACKBONE STATE PARK (CABINS & SPILLWAY)	IA0075876	MAQUOKETA RIVER	OTHER	89	0.007	0.0089
DNR BACKBONE STATE PARK (RANGER'S RESIDENCE)	IA0076937	MAQUOKETA RIVER	OTHER	6	0	0.0002
DNR MANCHESTER TROUT HATCHERY	IA0002275	SPRING BRANCH	WASTE STABIL LAGOON	101	0.007	0.0089
DNR MAQUOKETA CAVES STATE PARK	IA0076473	DRAINAGE DITCH TO RACCOON CREEK TO MAQUOKETA RIVER	2 CELL WASTE STABILIZAT-ION LAGOON*	53	NA	0.0125
DUNDEE CITY OF STP	IA0062839	MAQUOKETA RIVER	WASTE STABIL LAGOON*	232	0	0
EARLVILLE CITY OF STP	IA0042773	PLUM CREEK	TRICKLING FILTER	970	0	0.023
EDGEWOOD CITY OF STP	IA0024490	HONEY CREEK	AERATED LAGOON	1796	0.075	0.085
EDINBURGH MANOR OF JONES COUNTY	IA0065960	DRY CREEK BED TO MINERAL CREEK TO MAQUOKETA RIVER	WASTE STABIL LAGOON	150	0.119	0.203
GREELEY CITY OF STP	IA0040291	PLUM CREEK	WASTE STABIL LAGOON	518	0	0.015
HOPKINTON CITY OF STP	IA0023469	UNNAMED TRIBUTARY TO MAQUOKETA RIVER	SEQ BATCH REACTOR	1425	0.029	0.048
LAMONT CITY OF STP	IA0025348	LAMONT CREEK TO SOUTH FORK OF MAQUOKETA RIVER	WASTE STABIL LAGOON*	683	0.071	0.167
ONSLOW CITY OF STP	IA0057134	BEERS CREEK	WASTE STABIL LAGOON*	479	0	0.0644

(Table 7b continued)

PENN CENTER, INC.	IA0065854	UNNAMED TRIBUTARY TO MAQUOKETA RIVER	WASTE STABIL LAGOON*	60	0	0.0346
RYAN CITY OF STP	IA0041785	BUCK CREEK	WASTE STABIL LAGOON*	449	0	0.007
STRAWBERRY POINT CITY OF STP(NORTH)	IA0042765	KLEINLEIN CREEK	WASTE STABIL LAGOON	389	0	0.07
STRAWBERRY POINT CITY OF STP(SOUTH)	IA0042757	COUNTY DRAINAGE DITCH TO FENCHEL CREEK	WASTE STABIL LAGOON*	1650	0.0266	0.0729
WYOMING CITY OF STP	IA0032646	BIG BEAR CREEK	WASTE STABIL LAGOON*	856	0	0.15
WYOMING CITY OF STP	IA0032646	BIG BEAR CREEK	WASTE STABIL LAGOON	856	0.057	0.095

*** Denotes controlled discharge**

Livestock Feeding Operations

Livestock operations in the Maquoketa River watershed range in size from small farms with a few animals to large feeding operations. Open feedlots are unroofed or partially roofed animal feeding operations in which no crop, vegetation, forage growth, or residue cover is maintained during the period that animals are confined in the operation. Runoff from open feedlots can deliver substantial quantities of pathogen indicators, nutrients and oxygen demanding materials to a waterbody dependent upon factors such as proximity to a water surface, number and type of livestock and manure controls. Open feedlots with more than 1,000 animal units are required to have an operating permit or NPDES permit. In addition, Iowa has a voluntary registration program for open feedlots.

Confinement animal feeding operations (CAFOs) are animal feeding operations in which animals are confined to areas that are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application. Nutrients from CAFOs are delivered via runoff from land-applied manure or from leaking/failing storage structures. Currently, CAFOs with more than 500 animal units must have an approved manure management plan. Regardless of size, all CAFOs must report manure releases.

Nonpoint Sources

Nonpoint sources of bacterial pathogens include contributors that do not have localized points of release into a stream. In the Maquoketa River watershed these sources are:

- Land application of hog, cattle, and poultry manure
- Grazing animals
- Cattle contributions directly deposited in stream
- Failing septic systems and unsewered communities
- Urban areas
- Wildlife

The contributions from each of these sources are estimated using information available. The United States Environmental Protection Agency (EPA) contacted several agencies to refine the data assumptions made in determining the fecal loading. IDNR and Iowa State University (ISU) wildlife biologists provided information regarding deer and geese populations in the watershed. County sanitarians estimated the failure of septic tank systems in the state. The Natural Resources Conservation Service (NRCS) and ISU researchers provided valuable information on manure application practices and loading rates for hog farms and cattle operations. The location and magnitude of these loads are related to the different land uses in the Maquoketa River Watershed.

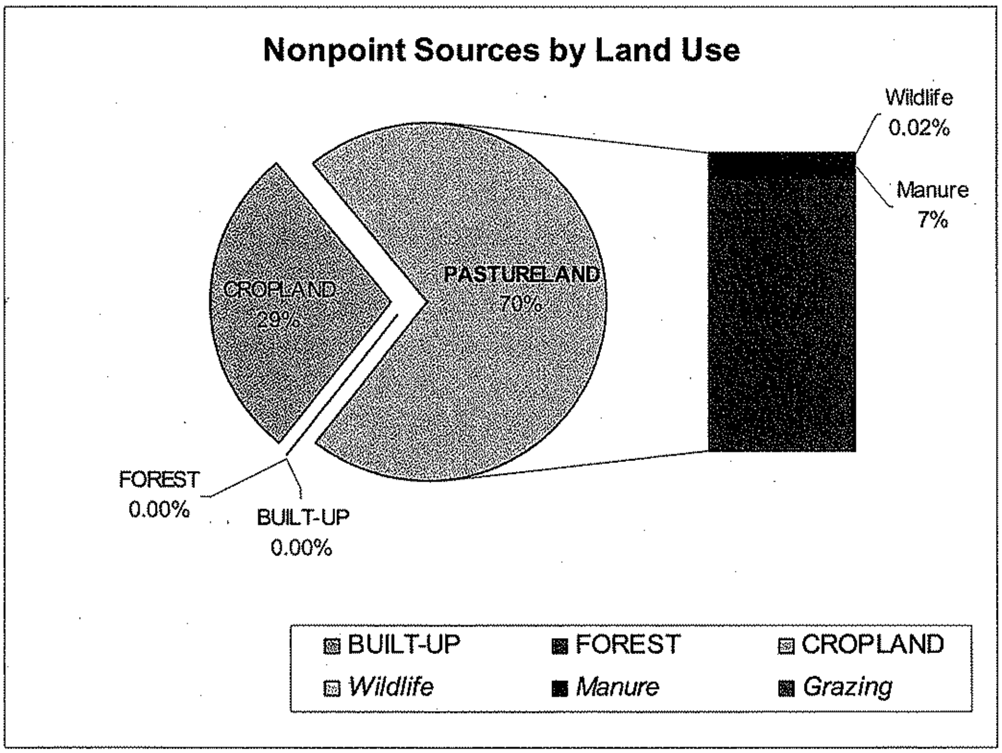

Figure 4. Nonpoint Sources of *E. coli* by Land Use.

Livestock Estimates for the Watershed

Table 8 provides the estimated number of animals in the Maquoketa River watershed, including dairy cows, beef cattle, and hogs. The animal inventory estimates are based on the 2002 Census of Agriculture, which was conducted in December of that year. Participants were asked to report the number of animals present at that time. Although livestock inventory can vary throughout the year depending on sale and slaughter rates, it is assumed that the Census numbers are representative of the average population throughout the year. The county level data was reduced by calculating the percentage of the county that is part of the watershed, assuming an even distribution of livestock.

Table 8. Estimated animals in the watershed.

Dairy Cows	Beef Cattle	Hogs	Chickens	Sheep	Horses
14,494	123,074	310,591	86,560	2,864	1,335

Land Application of Manure and Litter

Land application of manure from these sources is a potential contributor of bacteria to receiving waterbodies due to rain event or snowmelt runoff. Manure application rates vary monthly according to management practices currently used in the area. In general, the majority of manure is applied during the months of October, November, and December in this area of Iowa. Cattle manure is assumed to be applied to cropland and pastureland, whereas hog and poultry litter is only applied to cropland. While there are some alternative uses of poultry litter, such as utilization as cattle feed, almost all is used as fertilizer. It is assumed that horse manure is applied only to pastureland.

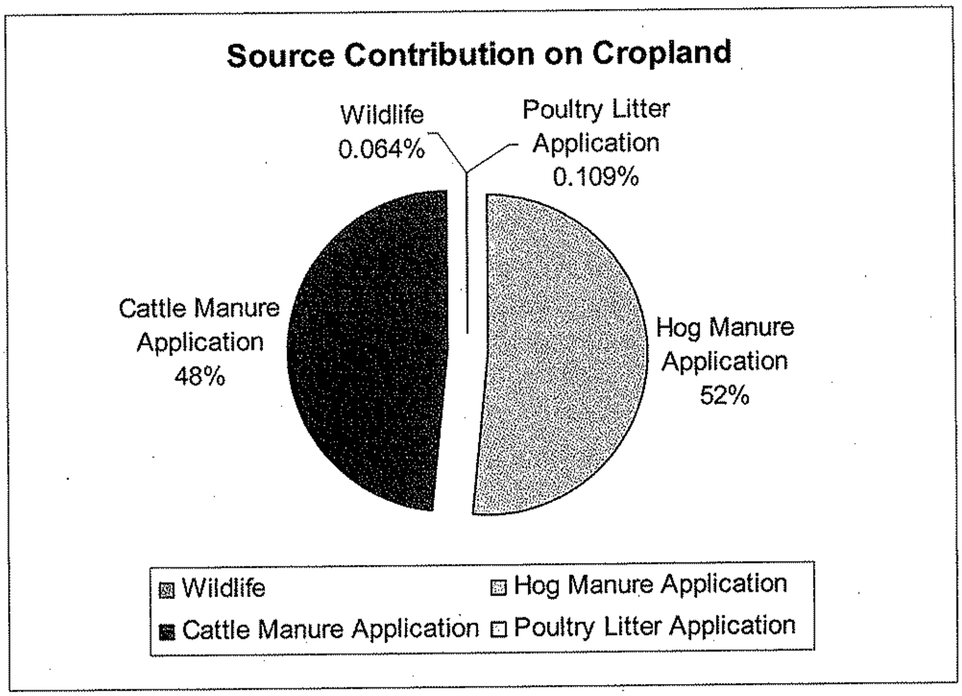

Figure 5. Cropland *E. coli* from land application manure, litter and wildlife.

Grazing Animals
Cattle, horses, and sheep spend time grazing on pastureland and deposit manure onto the land. During a rain event, a portion of this fecal matter is available for wash-off and delivery to receiving waterbodies. Figure 6 shows pastureland *E. coli* sources by percentage of contribution.

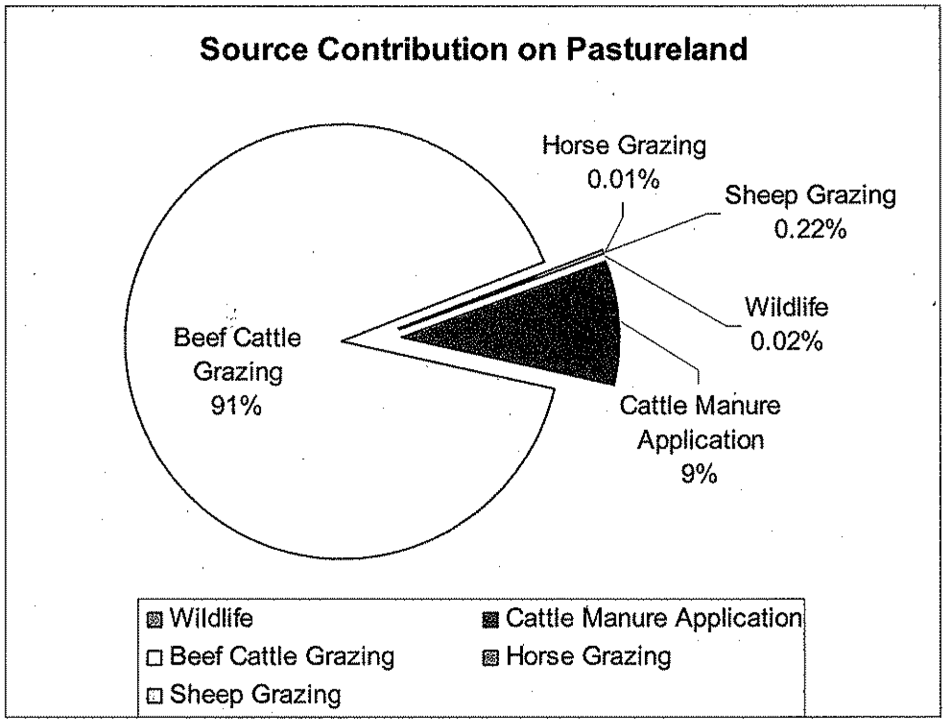

Figure 6. Pastureland *E. coli* from Animal grazing, cattle manure application and wildlife.

Access to pastureland for grazing cattle varies throughout the year. According to researchers at Iowa State University, cattle are 80% confined from January to March. During the spring and summer months (April through October) they spend 100% of their time grazing. In November and December, they have slightly reduced access and spend approximately 80% of their time grazing (Russell, personal communication). It was assumed that dairy cattle are confined in feedlots, and thus their waste is applied as manure. The grazing schedule for sheep is similar to cattle except that sheep tend to be fully confined during the months of January through March. It is assumed that horses are primarily grazing and spend negligible time confined. As such, they directly deposit manure to pastureland.

Cattle Contributions Deposited Directly In-stream
Cattle often have direct access to streams that run through pastureland. In Iowa the majority of cattle have direct access to a stream (approximately 90%). *E. coli* bacteria deposited in these streams by grazing cattle are modeled as a direct input of bacteria to the stream. Preliminary research data in Iowa indicate that cattle spend one to six

percent of their time in streams from April through December (Russell, personal communication).

Failing Septic Systems

Septic systems may deliver bacteria loads to surface waters due to malfunctions, failures, or direct pipe discharges. Properly operating septic systems treat the wastewater and dispose of the water through a network of perforated pipes in trenches called a lateral field. The water is applied through these field pipes into a porous substrate and then is absorbed underground. The systems can fail when the field lines are broken, or the underground substrate is clogged or flooded. The septic water reaches the surface and is then available for wash-off into the stream. Direct bypasses from septic tanks to a stream also lead to bacteria contamination. In efforts to keep wastewater from seeping up in a drain field, pipes are sometimes laid from the septic tanks or the field lines to the nearest stream.

Another consideration is the use of individual onsite wastewater treatment plants that are sometimes used when a septic tank and lateral field cannot be constructed to code. These can provide adequate treatment if properly maintained but often are neglected over the long term. Although required, disinfection is not usually provided.

The number of septic systems was estimated from the watershed area normalized count of septic systems in each county (USDC, 1992). Population and housing data were taken from the 2000 U. S. Census. The percent of households having septic systems was estimated using 1990 U.S. Census data which was the latest available that provided information on septic systems. County sanitarians were contacted for estimated rates of failure and normalized the rates based on the percentage of each county contained in the watershed to obtain an estimate for the Maquoketa River Basin. It is estimated that 45 percent are currently failing in the Maquoketa River Watershed. Table 9 displays information regarding septic systems in the watershed.

Table 9. Septic system information for each county in the Maquoketa River Watershed.

County	Septic tanks or cesspools	Household size	Number of persons served	Failure rate
Buchanan	297	2.52	7,386	40%*
Clayton	137	2.28	8,707	50%
Clinton	61	2.40	9,675	40%*
Delaware	2,522	2.43	8,764	50%
Fayette	232	2.36	7,714	65%
Jackson	344	2.37	6,992	33%
Jones	1,652	2.64	7,911	40%*
Linn	114	2.47	19,929	0%
Mean	5,359	2.49	13,352	45%

*No failure rate estimate could be obtained. Assume average of other counties is representative of these counties.

Urban Development

Pathogen contributions from urban areas may come from runoff through stormwater sewers (e.g. residential, commercial, industrial, and road transportation), illicit discharges of sanitary wastes, and runoff contribution from improper disposal of waste materials. The failure of sewer and septic systems and subsequent migration with stormwater runoff is also a potentially significant source. Twenty-one incorporated communities are entirely or partially in the watershed, and developed land use accounts for approximately 3% of the watershed.

Wildlife

Wildlife in the Maquoketa River Watershed contributes *E. coli* bacteria onto the land surface where it is available for wash-off during a rain event. In the Maquoketa River model, wildlife is accounted for by considering contributions from deer, geese, and raccoons. County-wide deer population estimates were obtained from IDNR wildlife biologists. These estimates were used to calculate an estimate for the watershed based on the percentage of each county within the watershed. The deer population is estimated to be 11 animals per square mile for this area. Geese populations are difficult to estimate. The estimate of 3 geese per square mile was used based on other Iowa TMDLs and conversations with wildlife biologists. Information regarding raccoon populations was obtained from Iowa State University researchers. The raccoon population in this part of Iowa varies seasonally from approximately 15 animals per square mile to 75 animals per square mile (Clark, personal communication). The tool used to estimate the bacteria contribution from various sources is limited in its ability to represent seasonal variation. Due to this, an average value of 45 animals per square mile was used for pastureland and forest cover. The minimum density estimate of 15 animals per square miles was used for cropland with the understanding that it may be marginal or unsuitable habitat during portions of the year. While the estimates may overestimate the populations in some instances, they compensate for the inability to obtain data for other wildlife populations, such as ducks, beaver, opossum, squirrel, and rabbit. The estimates are limited by the assumption that the wildlife population remains constant throughout the year, and that wildlife is present on all land classified as forest land, pastureland, cropland, and wetlands. It is also assumed that the wildlife is evenly distributed throughout the aforementioned land use types.

3.3 TMDL Target

Modeling Approach

The modeling approach uses a flow duration analysis to display excursions above the standard at different flow conditions. The flow was measured for a period from 1998 to 2004 at the Maquoketa River Gage located near Maquoketa, Iowa. Figure 7 shows the distribution of flow. The data is plotted against a statistically derived scale (Pearson Probability), in which a naturally flowing system will plot near a straight line. The flow record was then evaluated to separate baseflow from surface runoff. A digital filter technique was used to separate the hydrograph (Eckhardt, 2004). An example of the baseflow separation is shown in Figure 8.

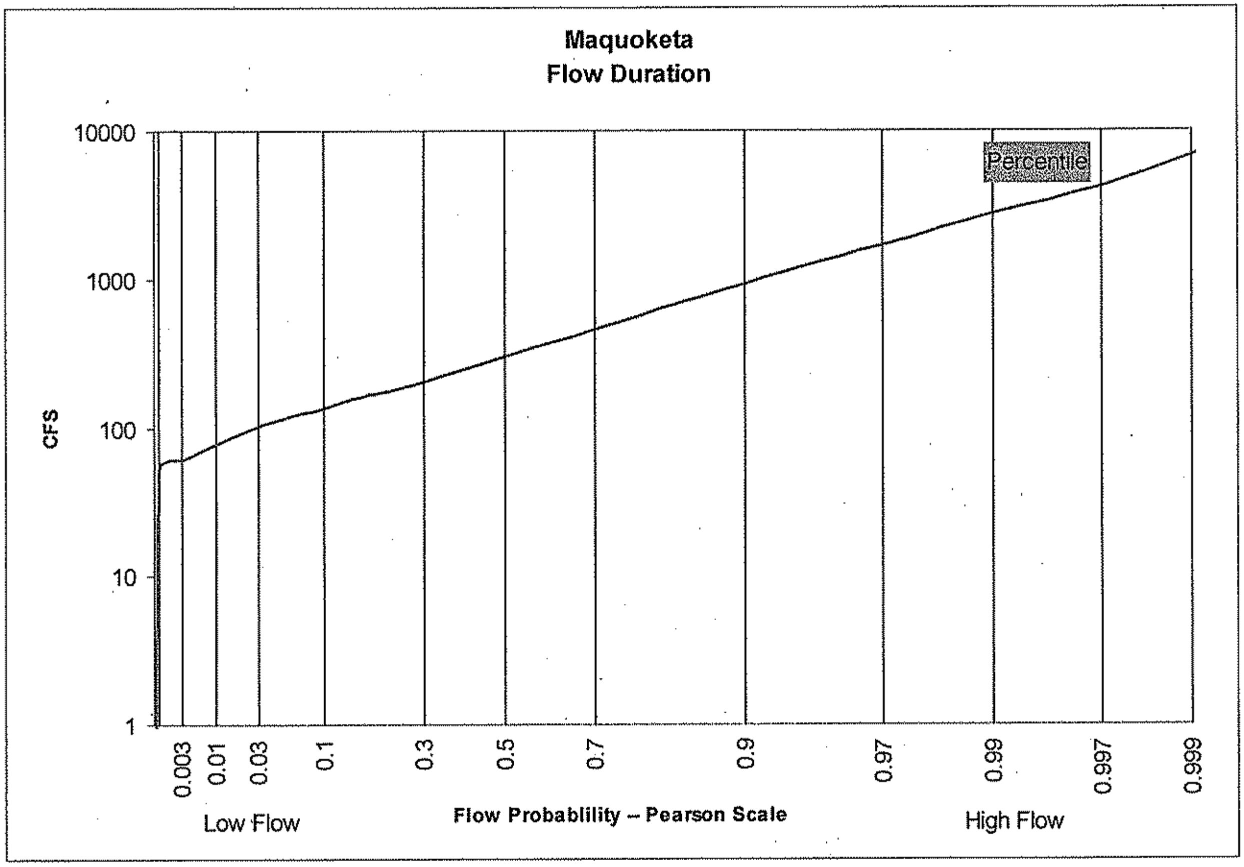

Figure 7. Probability that flow will exceed the value shown on the y axis.

Results of the source inventory were used to estimate nonpoint source loading by using EPA's "Bacterial Indicator Tool" (BIT) spreadsheet. The nonpoint source daily loading from the BIT was assumed to contribute only during surface runoff conditions as identified by the baseflow separation, otherwise it was allowed to accumulate on the land surface to a maximum of 9 times the daily generation. This approach is similar to that used in the HSPF (Bicknell et al., 2001) model and is consistent with that used in other TMDLs across the country (Virginia, 2003). Contributions of bacterial contamination during baseflow periods were attributed to cattle in the streams, septic tanks, unsewered communities, and a generalized loading that includes contribution from point sources. A release rate first order equation was used to simulate how land manure would be released (Shelton, 2003) and another first order decays for transport of the bacteria was also used (USEPA, 2001). To estimate travel times, time of concentration was estimated using distance to the impaired segment and an average flow velocity of sixteen miles per day (Neitsch, 2000).

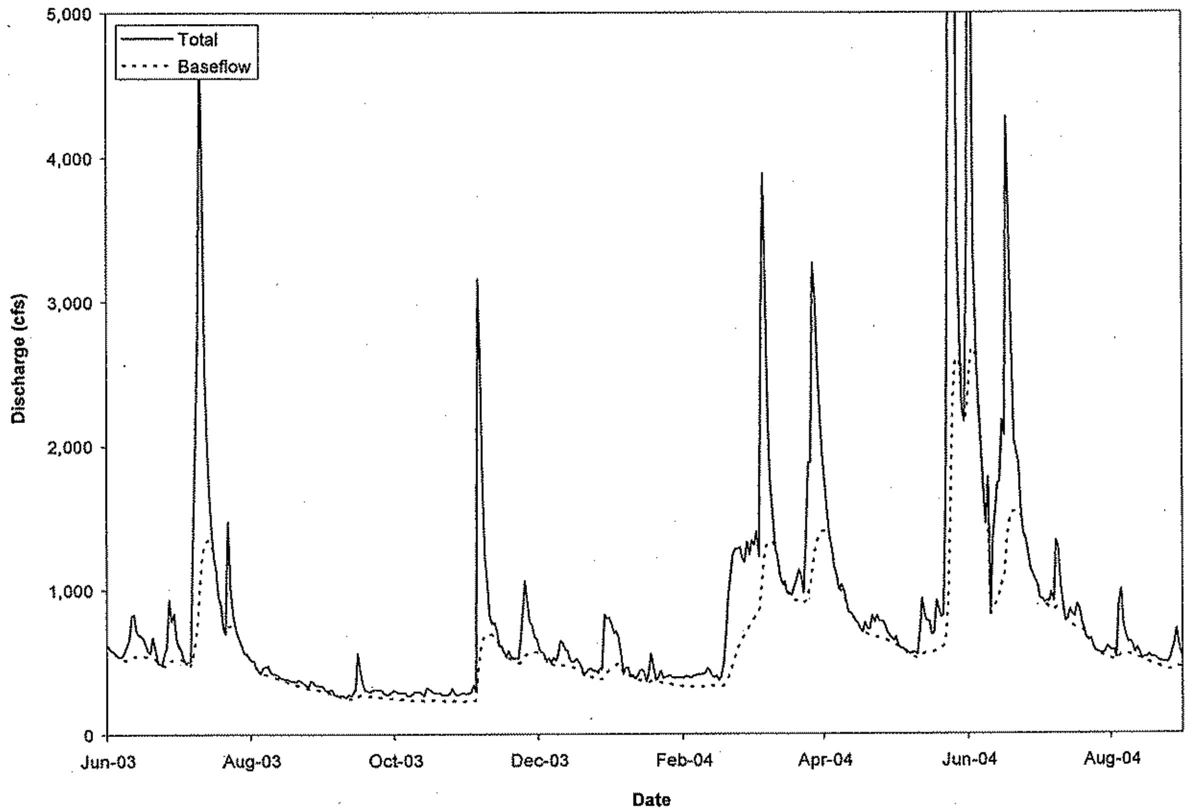

Figure 8. Example time period depicting the baseflow separation.

Waterbody Pollutant Loading Capacity

As previously explained, waterbody loading capacity for bacterial pathogens cannot be reasonably expressed as a mass per time. Because the risk and corresponding water quality criteria associated with bacteria are based on epidemiological studies relating illness rates to concentration, this TMDL is expressed as a relationship of concentration at a continuum of flow conditions, as shown on the duration curve in Figure 9.

Existing Load

Existing loads are shown in Figure 9, with notable seasonal variation. Loads carried by the river are generally highest in spring and summer, and tend to be low during the winter due to slowed bacterial activity, frozen conditions, and lack of surface runoff. Spreadsheet modeling was performed to predict the current fecal coliform bacteria concentrations, and regression analysis was used to validate the results. The regression analysis of observed versus the predicted concentrations of fecal coliform bacteria was statistically significant and had a correlation coefficient of 0.34, thereby explaining over one-third of the sample variability. Other measures of modeling effectiveness were calculated and are included in the spreadsheet model.

Linkage of Sources to Target

Figure 10 illustrates how the pollution sources were linked to the impairment. The load duration approach relates the bacterial concentrations to variable flow conditions, and percent surface runoff is shown to demonstrate the strong relationship between bacterial concentration and the presence of surface flow.. The TMDL target concentrations of bacteria are displayed for both the single sample maximum (SSM) and the geometric mean (GM). Figure 10 shows that when flow is less than the 50th percentile, there are few excursion of the single sample maximum (SSM), whereas at flows above this percentile, surface runoff is much higher as well as the frequency of exceedance of the criteria. The conclusion is that control of nonpoint sources will be required to achieve the standard.

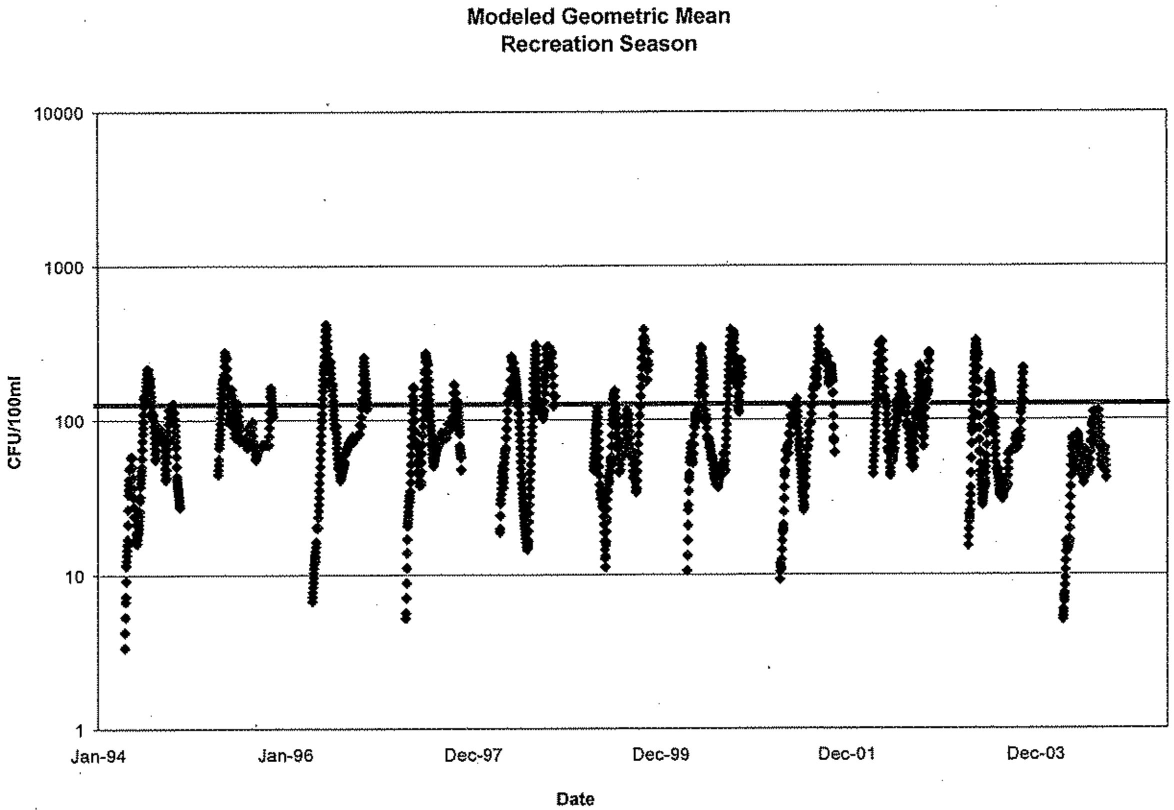

Figure 9. Modeled projection of existing bacteria concentrations compared to the 126 CFU/100 ml standard for *E.coli.*

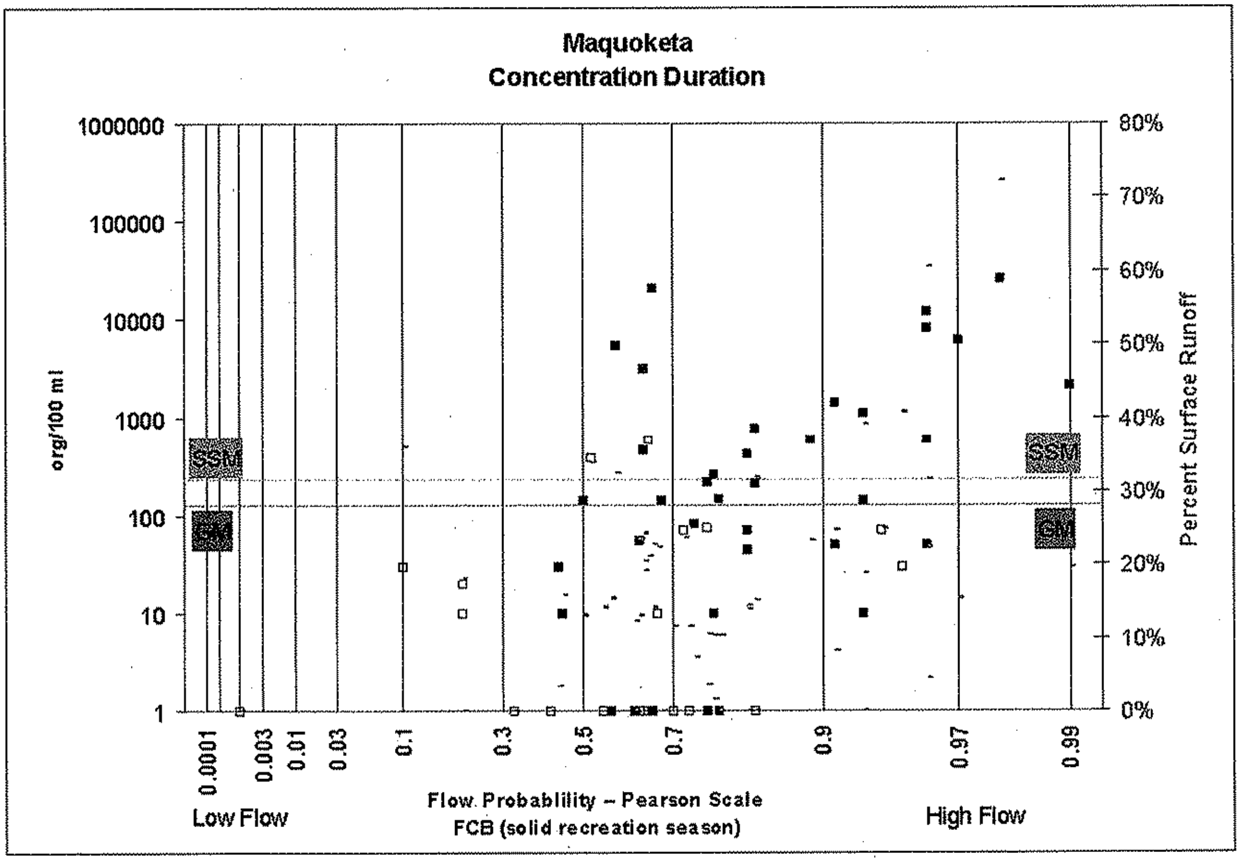

Figure 10. Sample results shown for various flow conditions and the estimated percent coming from surface runoff using the baseflow separation.

3.4 Pollutant Allocation

Wasteload Allocation

Point sources do not appear to be contributing to the impairment in this segment of the Maquoketa River, as indicated by the previous modeling results. Therefore, the total wasteload allocation for this TMDL is set to the existing target levels for *E. coli* water quality standards of 126 CFU/100 ml (geometric mean) or 235 CFU/100 ml (single sample maximum).

Specific wasteload allocations (WLAs) have been set for each permitted treatment facility above the impaired segment, to be measured in fecal coliform bacteria concentrations (CFU/100 ml) (Table 10). These WLA values were calculated by the EPA using the current *E. coli* water quality standards for Iowa while accounting for the amount of bacterial die-off that will occur within the stream before loads reach the impaired segment (USEPA, 2001). Thus, for facilities which discharge indirectly to the Maquoketa River (via tributaries upstream of the impaired segment), the wasteload allocations are set higher than 126 CFU/100 ml (geometric mean) and 235 CFU/100 ml (single sample maximum). Facilities that discharge directly to the receiving waterbody, however, must not exceed the current water quality standards in terms of end-of-pipe fecal coliform concentrations. The four facilities which currently have effluent limits for fecal coliform written in their NPDES permit (from Table 7a) will require reductions in their permit limits based on the WLAs given in Table 10.

Table 10. Wasteload Allocations (WLA).

Permitted Municipal/Semi-Public Treatment Facilities			Decay Coefficient			0.96
(*Four facilities in the watershed have fecal coliform permit limits)			Stream Velocity (miles per day)			16
Name	NPDES ID	Receiving Stream	Miles to Impaired Reach	Fraction after Decay	WLA (Fecal coliform CFU/100 ml) Geo-Mean	WLA (Fecal coliform CFU/100 ml) Daily Max.
*CAMP COURAGEOUS OF IOWA	IA0071820	UNNAMED TRIB TO MAQUOKETA RIVER	7.6	0.62	203	379
*CITY OF MANCHESTER STP	IA0021032	MAQUOKETA RIVER	0	1	126	235
*CITY OF MAQUOKETA STP	IA0024481	MAQUOKETA RIVER	0	1	126	235
*CITY OF MONTICELLO STP	IA0026034	MAQUOKETA RIVER	0	1	126	235
BALDWIN CITY OF STP	IA0063398	BEAR CREEK	7.2	0.64	197	367
DELAWARE CITY OF STP	IA0062855	PENN CREEK	14.5	0.4	315	588
DELHI CITY OF STP	IA0047848	UNNAMED CREEK TO MAQUOKETA RIVER	1.7	0.9	140	261
DNR BACKBONE STATE PARK (LOWER AREA)	IA0066044	DRY RUN TO MAQUOKETA RIVER	0	1	126	235
DNR BACKBONE STATE PARK (CABINS & SPILLWAY)	IA0075876	MAQUOKETA RIVER	0	1	126	235
DNR BACKBONE STATE PARK (RANGER'S RESIDENCE)	IA0076937	MAQUOKETA RIVER	0	1	126	235
DNR MANCHESTER TROUT HATCHERY	IA0002275	SPRING BRANCH	1.9	0.89	142	264
DNR MANCHESTER TROUT HATCHERY	IA0002275	SPRING BRANCH	1.9	0.89	142	264

(Table 10 continued)

DNR MAQUOKETA CAVES STATE PARK	IA0076473	DRAINAGE DITCH TO RACCOON CREEK TO MAQUOKETA RIVER	1.3	0.92	137	255
DUNDEE CITY OF STP	IA0062839	MAQUOKETA RIVER	0	1	126	235
EARLVILLE CITY OF STP	IA0042773	PLUM CREEK	14	0.42	300	560
EDGEWOOD CITY OF STP	IA0024490	HONEY CREEK	12.5	0.46	274	511
EDINBURGH MANOR OF JONES COUNTY	IA0065960	DRY CREEK BED TO MINERAL CREEK TO MAQUOKETA RIVER	4.5	0.75	168	313
GREELEY CITY OF STP	IA0040291	PLUM CREEK	27	0.18	700	1306
HOPKINTON CITY OF STP	IA0023469	UNNAMED TRIB TO MAQUOKETA RIVER	0	1	126	235
LAMONT CITY OF STP	IA0025348	LAMONT CREEK TO SOUTH FORK OF MAQUOKETA RIVER	3.9	0.78	162	301
ONSLOW CITY OF STP	IA0057134	BEERS CREEK	9.7	0.55	229	427
PENN CENTER, INC.	IA0065854	UNNAMED TRIB TO MAQUOKETA RIVER	1.2	0.93	135	253
RYAN CITY OF STP	IA0041785	BUCK CREEK	15	0.39	323	603
STRAWBERRY POINT CITY OF STP(NORTH)	IA0042765	KLEINLEIN CREEK	3.6	0.8	158	294
STRAWBERRY POINT CITY OF STP(SOUTH)	IA0042757	CO. DRAINAGE DITCH TO FENCHEL CREEK	3.6	0.8	158	294
WYOMING CITY OF STP	IA0032646	BIG BEAR CREEK	23.5	0.23	548	1022
WYOMING CITY OF STP	IA0032646	BIG BEAR CREEK	23.5	0.23	548	1022

Load Allocation

To achieve the target indicator pathogen load, reductions in nonpoint sources will be necessary. Modeling suggests that to meet the water quality standards, a 78% reduction in bacterial loads delivered via surface runoff and 40% reduction in other NPS bacterial loads (e.g., septics and cattle in the stream) must be achieved. Figure 11 shows the expected results of those reductions.

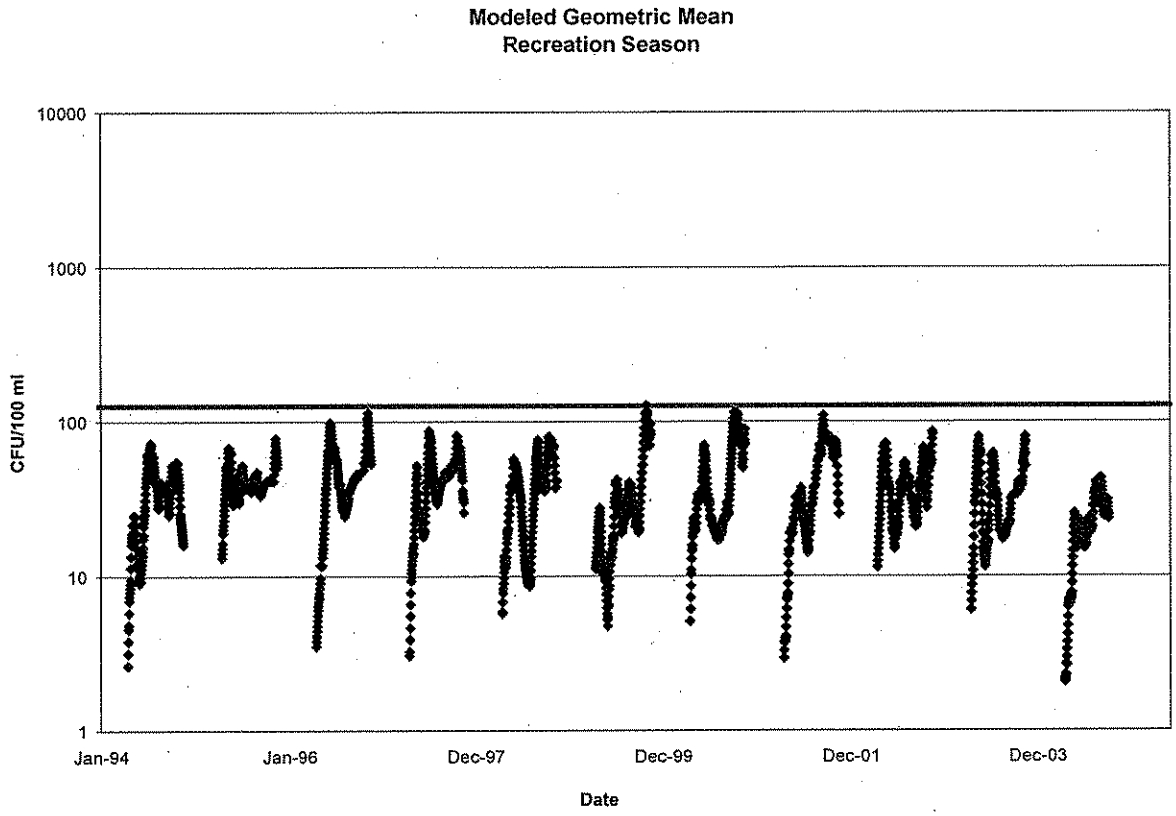

Figure 11. Expected *E. coli* concentrations based on the suggested TMDL reductions in nonpoint source loads.

Margin of Safety

Because of the data consideration that *E. coli* is a subset of fecal coliform, it follows that in a given sample, the *E.coli* level will always be less than the corresponding fecal coliform level. This TMDL is expressed as a percentage of reduction in loading to achieve a fecal coliform target which is set at the *E. coli* standard. The margin of safety is thereby explicit due to targeting fecal coliform reductions at the *E.coli* standard level. Since there is no EPA-approved method for measuring *E. coli* concentrations from wastewater effluent, fecal coliform concentrations should be measured to meet the 126 CFU/100 ml geometric mean or 235 CFU/100 ml single sample maximum water quality standards.

4. IMPLEMENTATION PLAN

The following implementation plan is not a required component of a Total Maximum Daily Load but can provide department staff, partners, and watershed stakeholders with a strategy for improving Maquoketa River water quality. This plan follows with the phased TMDL approach in which specific reductions will be suggested, practices implemented, and the effects monitored over time to determine if improvements can be seen and if further work is needed.

As discussed previously, modeling and analysis suggests the following is needed:

- 78% reduction in bacterial loads delivered by surface runoff (from cropfields, pastures, and other areas)
- 40% reduction in other bacterial load sources such as septics and cattle delivering directly to streams
- Fixed reductions in fecal coliform limits from wastewater effluent as dictated by this TMDL

Land management changes to achieve such reductions will take time to implement, as will measurable changes to stream water quality. Since it is difficult to actually measure the reductions in source loading as specified above, efforts should be focused on implementing practices that address known problem areas to achieve overall reductions.

4.1 Surface runoff loads

Reductions in surface runoff loads could be achieved through a variety of means, including both in-field and riparian conservation best management practices (BMPs). These might include:

- Using appropriate manure application rates
- Manure injection/incorporation into subsoil as opposed to surface spreading
- Feedlot runoff control
- Open pasture runoff control
- Protection/rotation of areas where livestock congregate (loafing areas)
- Buffer strips along stream corridors for runoff interception
- Conservation tillage and rotations which improve infiltration and reduce surface runoff from fields
- Terracing and contour farming

These nonpoint sources mainly contribute to the pathogen impairment during storm events or snow melt and thus can be controlled much in the same way that soil erosion problems are commonly treated (i.e. settling, filtering). Priority should be placed on reducing runoff loads from feedlots and pasture lands where the majority of available source load exists (Figure 4), but also on croplands where manure is applied. It should be mentioned that although there is a strong connection between surface runoff and observed bacteria concentrations in the river, a direct cause-and-effect relationship between manure application and bacteria delivery cannot be implied.

4.2 Other bacterial loads (direct nonpoint sources)

Other bacterial loads such as those from septics and cattle in the stream represent continuous sources of pollutant loading and need to be addressed more directly by identifying their presence and eliminating the source. This might require:

- Exclusion of livestock from the stream
- Identifying and repairing failed septic systems
- Identifying and eliminating any uncontrolled discharges

4.3 Reasonable Assurance

Several local watershed groups have operated or are currently operating in the Maquoketa River watershed. Many operate under Clean Water Act Section 319 grants or Watershed Protection Fund grants from the Iowa Dept. of Agriculture and Land Stewardship Division of Soil Conservation (IDALS-DSC). Most of the groups are volunteer-based but are technically assisted by USDA, IDALS-DSC, and county extension agents. Therefore, a significant infrastructure currently exists to achieve improvements in the Maquoketa River watershed.

Comprehensive land use assessments have been completed or are currently being worked on for several sub-watersheds above the impaired segment, including: Mineral Creek, the upper Maquoketa River, South Fork of the Maquoketa, and the entire watershed above Lake Delhi. These assessments will be used in support of funded watershed protection projects and for prioritizing BMP placement at the watershed scale. In addition, local technicians and volunteers have worked or are working on stream corridor and streambank and feedlot assessments throughout certain areas of the watershed above the impaired stretch. All of this work should produce valuable information to help guide decision making and BMP implementation on the ground for future watershed work.

5. MONITORING

Water quality monitoring is ongoing at the IDNR ambient station on the Maquoketa River near Maquoketa, IA. At the current time no additional monitoring is scheduled, although seventeen candidate sites which were targeted for TMDL monitoring in 2001 offer potential locations for additional data collection.

Microbial source tracking (MST) is a technology used to determine the sources of fecal bacteria more specifically. Several MST methods are available and are being evaluated by DNR staff to determine the method(s) that are most feasible for Iowa lakes and streams. As a part of Phase 2, the DNR hopes to add MST to the monitoring plan as the technology becomes more accurate and affordable.

6. PUBLIC PARTICIPATION

Public meetings were held in July of 2005 to seek comments and input from local stakeholders for the development of the TMDL. Each of the three meetings were well-attended by interested citizens, media groups, local producers, environmental groups, lawmakers, and natural resource managers. Some recurring concerns that the public expressed at these meetings included: the inclusion of wildlife inputs to the total bacterial load (especially deer and geese); the need for thorough and well-organized water quality monitoring throughout the entire watershed; and the long-term need for assistance from the Iowa DNR and other government agencies to bring about changes and improvement to the Maquoketa River watershed. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

A second round of public meetings was held on August 2, 2006 in Maquoketa and at Backbone State Park to present the draft TMDL and allow for comments and suggestions on the final draft. These comments were also considered and incorporated into the final report.

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